ENERGY CONSERVATION FOR PRODUCTION OF 100,000 MT/A ISOBUTYLENE PLANT AND EFFECT TO THE PLANT ECONOMIC

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A report submitted in partial fulfilment of the requirements for the award of the degree of Bachelor of Chemical Engineering

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JUNE 2010

ABSTRACT

This research shows how the application of Pinch technology can lead towards great energy saving. A few step need to undergo before start a heat exchanger network design which, analysis of process flow diagram data, pinch analysis and economic analysis. The heat exchanger network of the isobutylene process plant has been studied and it was shows how the application of pinch technology makes it possible to reduce the demand of hot and cold utility. After design the heat exchanger network, the overall heat exchanger required in these process is seven heat exchanger and all of them need to be redesign. The energy saving for total cooling is 65% and for total heating 38% which mean the good investment. Heat recovery is slightly reduced as the different minimum temperature increase. Even though the value of capital investment is higher than original process, but by implement pinch analysis in this plant, energy saving for utilities can recover the capital investment. Pay back period for the project is 0.8 year (9 month 3 days) that means, this project can be classify as quick win project

ABSTRAK

Kajian ini menunjukkan bagaimana aplikasi teknologi cubitan boleh membawa kearah penjimatan tenaga. Beberapa langkah dilakukan sebelum memulakan pengubahsuaian rangkaian penukar haba, iaitu menganalisa proses gambarajah tapak isobutylene, teknologi cubitan dan menganalisa ekonomi. Kajian menunjukkan aplikasi teknologi cubitan berkemungkinan boleh mengurangkan penggunaan pemanasan dan penyejukan. Selepas pengubah suaian rangkaian penukar haba dijalankan, jumlah penukar haba yang diperlukan dalam proses ini adalah 7 dan semua daripadanya hendaklah diubahsuai semula. Penjimatan tenaga untuk jumlah penyejukan ialah 65 % dan untuk jumlah pemanasan ialah 38% yang membawa maksud pelaburan yang baik. Pemulihan tenaga adalah berkadar songsang dengan beza suhu minima. Pun begitu nilai modal yang dikeluarkan adalah tinggi berbanding dengan proses asal. Tapi oleh kerana teknologi cubitan dilaksanakan di dalam plant ini, maka penjimatan tenaga untuk penggunaan boleh diimbangi. Masa bayaran balik untuk projek ini adalah 0,8 tahun (9 bulan 3 hari) yang bermaksud, projek ini diklasifikasikan sebagai projek menang mudah.

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LIST OF ABBREVIATIONS

A_t	-	Heat transfer area
CC	-	Composite curve
CHP	-	Combined heat and power
CP	-	Heat capacity
C_{TM}	-	Total manufacturing cost
EAOC	-	Equivalent annual operating cost
FCI	-	Fix capital investment
F_t	-	Correction factor
GCC	-	Grand composite curve
HEN	-	Heat exchanger network
HENS	-	Heat exchanger network synthesis
MT/A	-	Metric Tonne per Annum
N_{cs}	-	Number of cold stream
N_{hs}	-	Number of hot stream
PI	-	Process integration
T_1	-	Hot fluid temperature inlet
T_2	-	Hot fluid temperature outlet
t_1	-	Cold fluid temperature inlet
t_2	-	Cold fluid temperature outlet
ΔT_{lm}	-	Log mean temperature different
$\Delta Tmin$	-	Minimum temperature different
U_o	-	Overall heat transfer coefficient

CHAPTER 1

INTRODUCTION

1.1 Introduction

In recent years, isobutylene has become an important product in industries because it is used as an intermediate chemical and largely used in polymerization process to produce the polisobutylene or that mostly used in butyl rubber industry. Isobutylene also were used in the MTBE industry. More that half of the butylenes produced worldwide are utilized as alkylate and polymer gasoline. Because of the market of isobutylene is continuously increased, more plant is designed annually. In the isobutylene plant, heat exchangers are widely used both for cooling and heating large scale processes. Heat exchanger process is desirable to increase the temperature of one fluid while cooling another make them are become major consumers of energy in process plant. Increasing of energy in a process plant can cause of producing a large quantity of carbon emission, which can cause global warming. This situation contributes to more study on energy conservation for chemical plant due to depletion of natural recourses and concern of environment. The integration of a new process into the existing facility provides significant improvements in the design of process plants that would minimize the net cost of energy purchase. The most useful tool that enables this design advance is pinch technology. It is a comprehensive and reliable technique to be applied in order to conserve the energy usage of a chemical plant and will contribute to sustainable and environmental friendly chemical process and has a significant economical impact on the plant's operation.

1. 2 Plant descriptions – production of 100,000 MT/A isobutylene

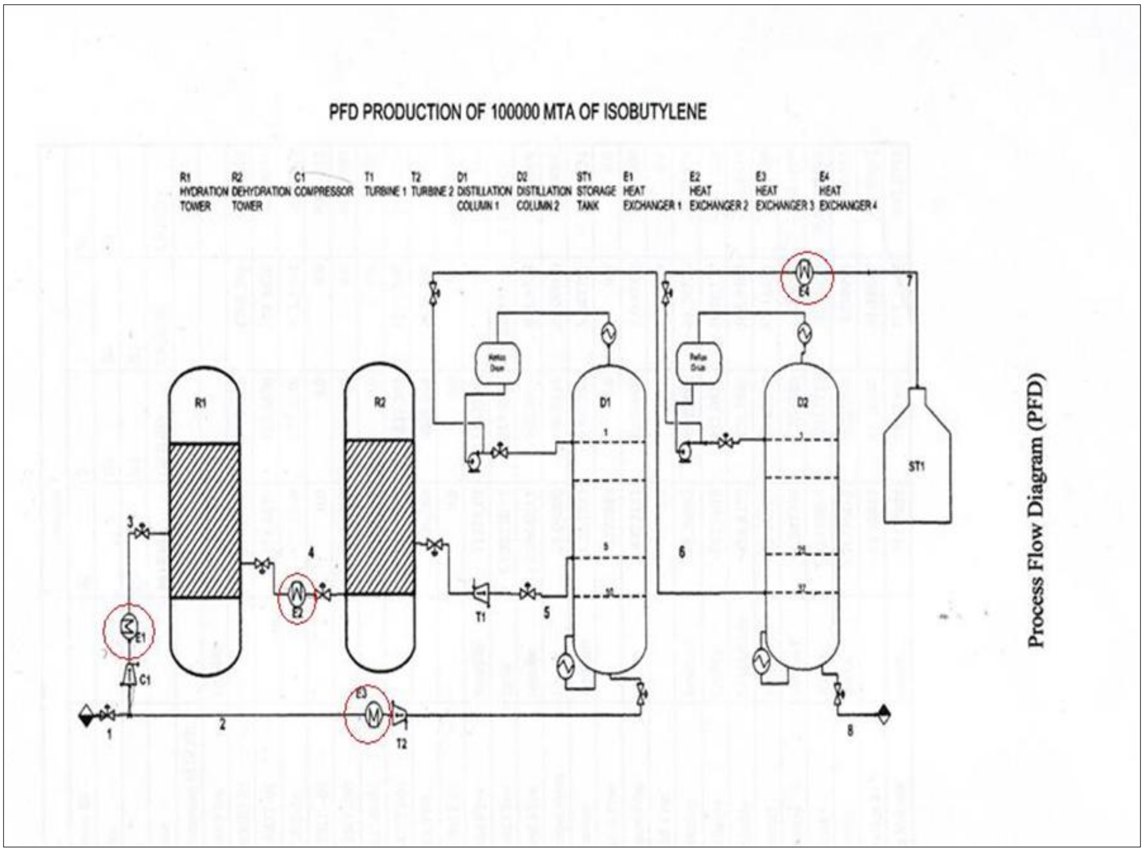

Figure 1.1: Process flow diagram for production of 100,000 MT/A of isobutylene.

Figure 1.1 show the process flow diagram for production of 100,000 MT/A of isobutylene. The process consists of four major process which are mixing process, hydration reaction, dehydration reaction and separation process using distillation column. These processes involve four heat exchangers, two distillation columns, two reactors, two turbines and a storage tank. From the process in figure 1.1 the focus of the study was made to the initial process whereby feed stream one to reactor one (R1) is heated, and inlet to a reactor two (R2) which is stream four the product stream is to be cooled. The heating and cooling are done by use of steam (heat exchanger-1) and cooling water (heat exchanger-2) respectively. Another stream that consists of heating and cooling process is at stream two and stream seven. When the process involves single hot and cold stream, it is easy to design an optimum heat recovery exchanger network. The data extracted for figure 1.1 is presented in table 1.1.

Table 1.1: Data extracted for production of 100,000 MT/A isobutylene.

Stream	Name	Ts, ^oC	Tt , ^oC	CP, kW/^oC	ΔH, kW
4	Hot 1	115	50	384.54	-24995.1
7	Hot 2	77	25	9.23	-479.96
1	Cold 1	50	106	420.5	23548
2	Cold 2	25	156.36	149.357	19619.53

1.2 Problem statement

Petrochemical plant is important energy users, especially thermal energy. From the aspect of economy, the total production cost to produce 100,000 MT/A isobutylene is RM 376,362,299 and this characteristic is the reason for the appearance of many studies about energy savings alternative in the petrochemical plant. Energy saving reflects itself in many ways, for example reduced fuel consumption or reduce maintenance cost due to the lower load on various items of plant equipment. However, until now finding the best configuration for process equipment and heat exchangers has been a complicated business. In plant design, there is always a trade-off between energy costs and the capital costs of heat exchangers and other equipment required to optimize energy efficiency. Energy saving in process plant equipment has essentially been a trial-and-error procedure between changes in structure and simulation until satisfactory reductions are achieved. It was very important to optimize the use of energy in the plant so that we can decrease the maintenance cost for the plant every year and minimizing usage of utilities in a process plant. Pinch technology, is a new energy analysis tool that allows design engineers to track the heat flow from all process streams in a system and identify modifications that can cut energy costs by 20 to 40 percent. It is a complete methodology derived from simple scientific principle by which it is possible to design new plant with reduced energy as well as where the existing process require modification to improved the performance. Using pinch technology it can provides an easy way to analyze the trade-offs of capital cost and energy efficiency

1.3 Objective

This aim of the study is to minimize the cost utility for a production of 10,000 MT/A Isobutylene plant. The objectives of the study were;

i.) To minimize the energy usage of the plant.
ii.) To study the effect of energy conservation to plant economic.
iii.) To find the different temperature minimum for isobutylene process.

1.4 Scope

i) To observe the effect of energy saving in the plant by using Pinch analysis method
ii) Analysis the effect of cost investment for new heat exchanger design
iii) Analysis the effect of pay back period to the plant economic

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Today's petrochemical industry is challenged by many circumstantial variations. Oil price has risen radically in the past three years and stays at high level. Regulations about environment are getting more difficult to comply. Many people think the chemical industry is harmful and hazardous and this brings about many troubles with NGOs or neighbors around the petrochemical complex. All of these problem give a badly effect to the chemical industry. In order to sustain growth, it is necessary for the chemical industry to come out with solution such as saving cost and raising productivity simultaneously with satisfying many regulations. Energy saving is the most important issue in the petrochemical industry associated with cost and regulations. Energy cost contributes significantly to the total cost and the budget of energy cost rises sharply due to high oil price recently. As an addition new imposed regulation, Kyoto Protocol, which restrains discharge of green house gases, is expected to require reduction of carbon dioxide discharge (S.G Yoon *et al*).

The increasing concern for the environmental impacts of human activities has stimulated the development of new methods for the analysis of industrial processes and the implementation of energy conservation measures. One particularly powerful method is pinch technology method, which matured during the last 15 year with major contribution from Linnhoff. The implementation of process integration methods can lead to significant energy savings and waste reduction (primary wastewater minimization). Some of the research centers (Gunderson T., 2000) reported that ‘‘Pinch technology is probably the best approach that can be used to obtain significant energy and water savings as well as pollution reductions for different kind of industries’’. Their experience, summarized for the wide variety of industrial processes (Fig. 2.1), points out the great potential for improving the efficiency of large and complex industrial facilities. This potential exceeded the results obtained by traditional audits, based on the separate optimization of individual process units.

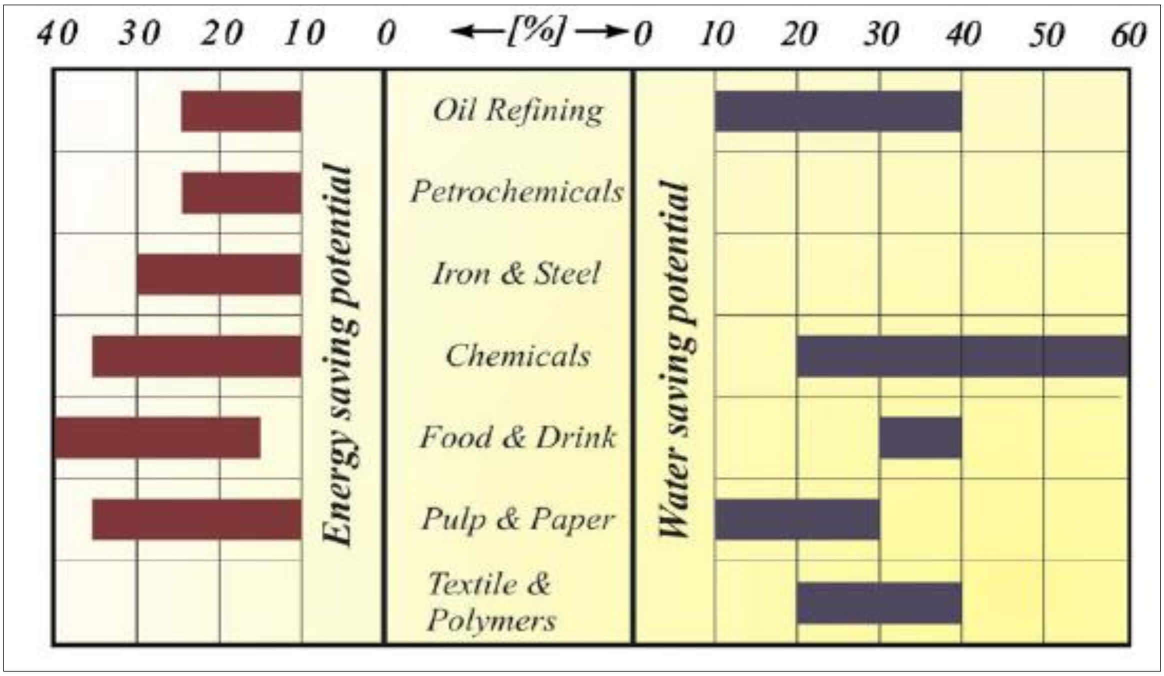

Figure 2.1: potential for reduction of energy and water consumption through Pinch analysis (Predrag et al., 2009)

2.1.1 Water uses and general approaches to water minimization within industry

In the production of 100,000 MT/A isobutylene plant (Azmin et al.,2009) its reported that the water utilities of the plant with specification RM 0.15 per 1000 kilogram cost almost RM 3 million per year. The cost of water utility can be reduced by using applied water minimization within the industry.

Most common water uses within a manufacturing facility in the process industries presented in figure 2.2. The figure illustrates common sources of wastewater, including process uses, condensate losses, boiler blowdown, and cooling-tower blowdown, wastewater from other uses such as housekeeping and storm-water runoff.

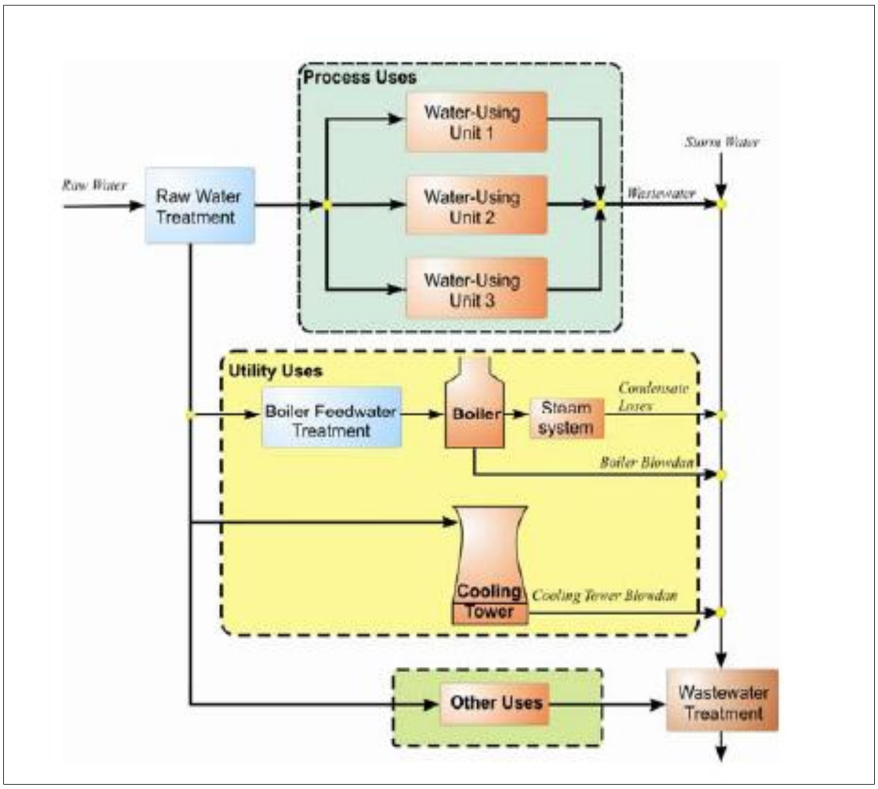

Figure 2.2: Typical water used on process site

Water is directed to process uses, utility uses or other uses. Four general approaches for the water minimization include process change, water reused, regeneration reuse and regeneration recycling.

2.1.1.1 Process change

A single source of fresh water is used to supply a variety of processes, *P*. Once used, the process waters are mixed and sent to a series of treatment operations, *T*, before discharge. Replacing the technology employed in a process can reduce the inherent demand for water. Sometimes it is possible to reduce water demand by changing the way existing equipment is operated, rather than replacing or modifying it (Rascovic.,2009) Figure 2.3 illustrated a process changes that involve in water minimization.

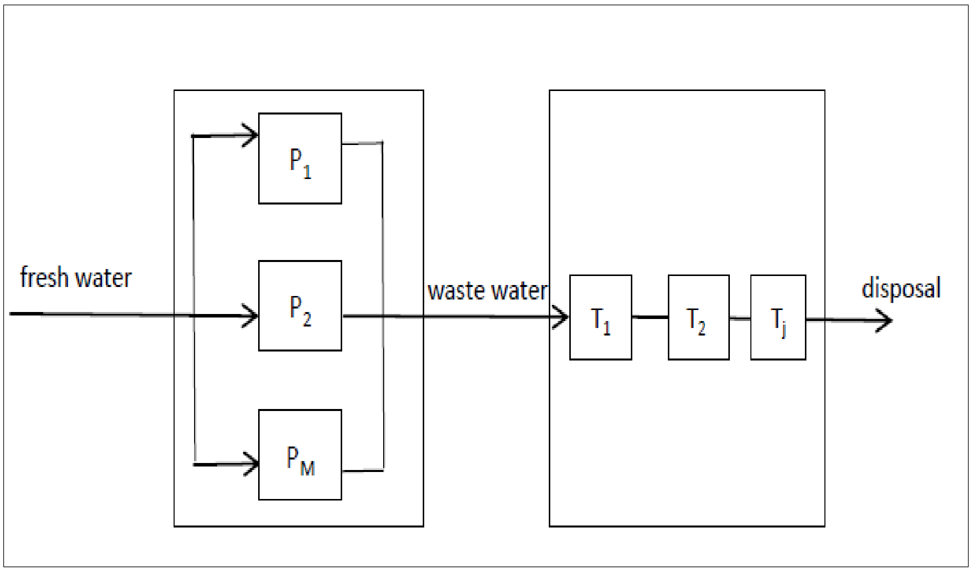

Figure 2.3: Process change

2.1.1.2 Water reused

The effluent from some process water uses can be used as the feed material for other process uses. Wastewater from one operation can be directly used in another operation, provided the level of contamination from the previous process does not interfere with the subsequent process. This will reduce overall fresh water and wastewater volumes, but not affect contaminant loads in the overall effluent from the system. Generally, reuse excludes returning, either directly or indirectly, to operations through which it has already passed, in order to avoid build-up of minor contaminants which have not been considered in the analysis.

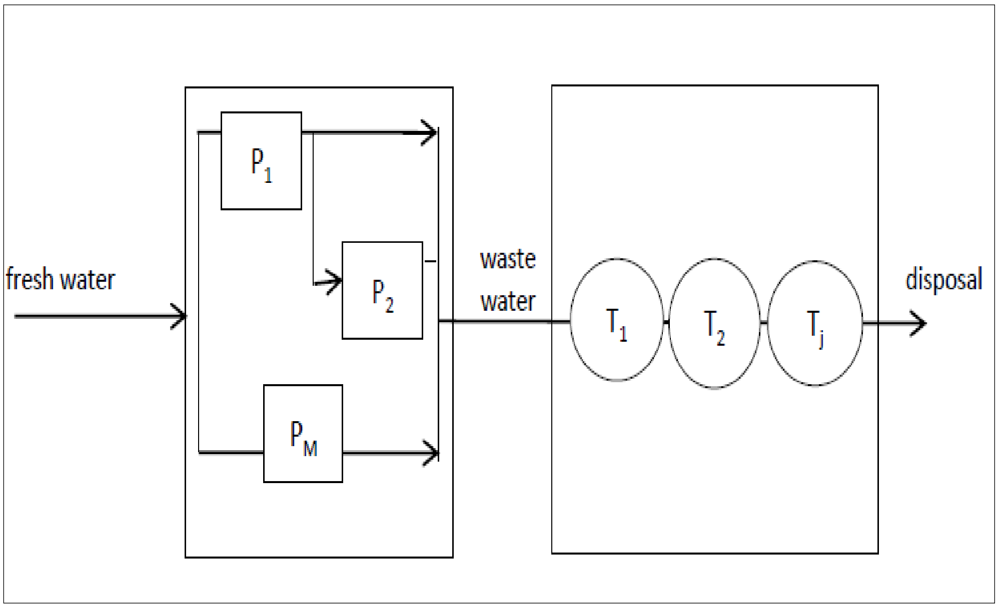

Figure 2.4: Water reused

2.1.1.3 Regeneration reused and recycling

Regeneration reuse is partial treatment of wastewater can remove contaminants which would otherwise prevent reuse. The regeneration process might be filtration, stream-stripping, carbon adsorption or other such processes. In this case both volumes and contaminant loads will be reduced. Where as regeneration recycling is refers to the situation where water is reused in an operation through which it has already passed. In this case, the regeneration step must be capable of removing all contaminants which build up in the system. Figure 2.5 illustrate of the regeneration reused and also regeneration recycling.

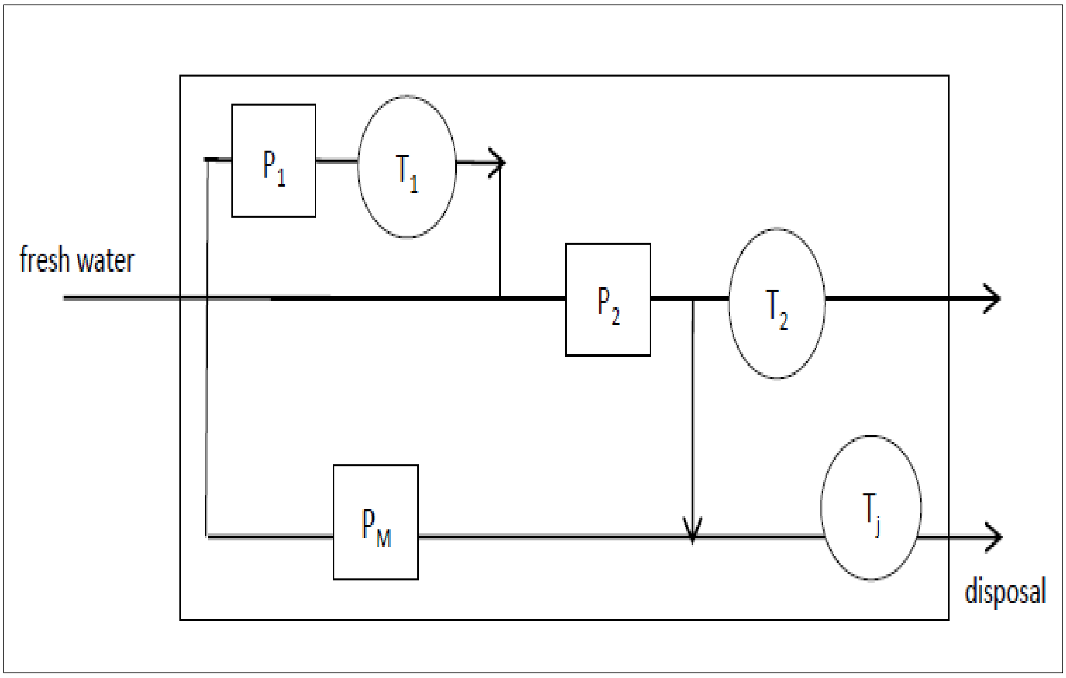

Figure 2.5: Regeneration reused

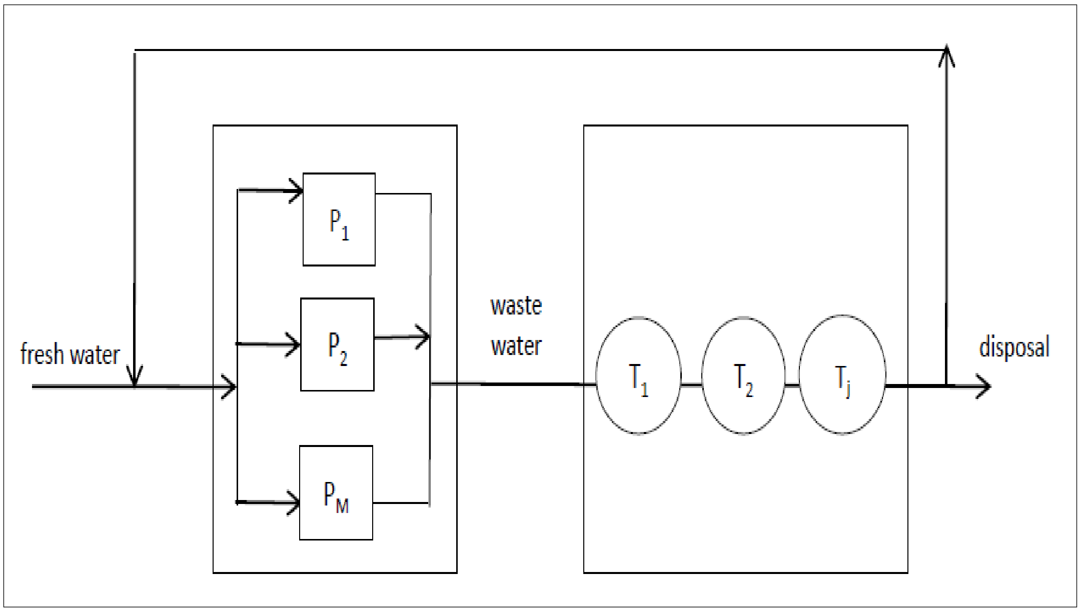

Figure 2.6: Regeneration recycling

2.2 Background of Pinch Analysis

In the late 1978, Bodo Linnhoff a Ph.D student from the corporate laboratory, Imperial Chemical Industries Limited, ICI, under the supervision of professor John Flower, University of Leeds, devised a new approach to describe energy flows in process heat exchanger networks (Kawari et al.,2000). It was an introduction of thermodynamic principles into what was then called ‘process synthesis’ and heat exchanger network design. Today, pinch technology has an established industrial track record. There are over 500 projects undertaken worldwide. The BASF Company alone has undertaken over 150 of these 500 projects. They have been able to achieve a saving of over 25 % of energy in their main factory at Ludwigshafen, Germany, by adopting this technique (Kawari et al.,2000).

Pinch technology is a complete methodology derived from simple scientific principles by which it is possible to design new plants with reduced energy and capital costs as well as where the existing processes require modification to improve performance. An additional major advantage of the Pinch approach is that by simply analyzing the process data using its methodology, energy and other design targets are predicted such that it is possible to assess the consequences of a new design or a potential modification before embarking on actual implementation. Pinch analysis originated in the petrochemical sector and is now being applied to solve a wide range of problems in mainstream chemical engineering. Wherever heating and cooling of process materials take place, there is a potential opportunity. The technology, when applied with imagination, can affect reactor design, separator design and the overall process optimization in any plant. It has been applied to process problems that go far beyond energy conservation. It has been employed to solve problems as diverse as improving effluent quality, reducing emission, increasing product yield and debottlenecking, increasing throughput and improving the flexibility and safety of the process (Akande et al.,2009)

2.3 Pinch Analysis

Recently the technique has been extended to address capital cost, in which the capital-cost target has been developed ahead of the design stage. An overall thermodynamic method has emerged which bring together energy and capital cost. In the beginning, the technique was applied for grass-root designs and subsequently it has been extended for the retrofits of old designs (Kawari et al., 2000). Pinch technique, which has evolved as an energy saving technique, present simple and easy ways of optimization based on complex thermodynamic rules. It is used to low operating costs, de-bottlenecking processes, raising efficiency and reducing capital investment. According to K.R Ajao and H.F Akande study on energy integration of crude distillation unit using pinch analysis shows that pinch analysis as an energy integration technique saves more energy and utilities cost than the traditional energy technique. The pinch design can reveal opportunities to modify the core process to improve heat integration. Pinch analysis is used to identify energy cost and heat exchanger network (HEN) capital cost targets for a process and recognizing the pinch point. Most processes need to consume energy at one temperature level and reject it at another level. This is achieved using utilities. Energy is provided to a process using such utilities as steam, hot water, and fuel gas it is rejected to cooling water, air, refrigerant or in heat recovery steam rising. Heat recovery is used to reduce the utility cost of a process. Evaluation of heat recovery involves a balancing of utility against the capital cost of the heat recovery system. The utility cost not only depends upon the amount of energy consumed and rejected but on the utility actually used (Akande et al., 2009) . From the curves shown in Fig.2.7, the performance of the plant can be determined and it will give a clear overall picture of the plant performance rather than having calculated the performance of each item of equipment individually (Kawari et al.,2000)

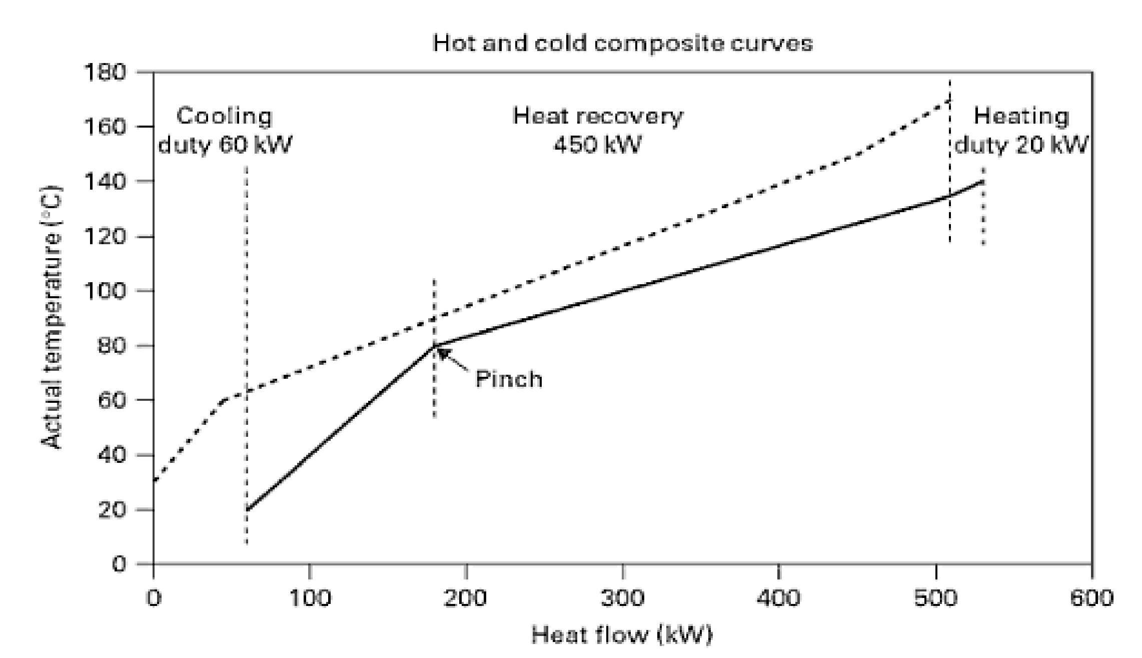

Figure 2.7: Pinch technology will convert the plant heat-exchanger streams to line called the hot and cold composites curve. (C.Kemp, 2007)

Pinch Technology provides a systematic methodology for energy saving in processes and total sites. The methodology is based on thermodynamic principles. Figure 2.8 show an onion diagram of process hierarchy in common process design. The design of a process starts with the reaction and chemical synthesis process (in the ‘core’of the onion). Then, the separation and process development (the second layer of the onion) can be start design after feeds, products, recycle concentrations and flow rates is identified. The basic process heat and material balance is now in place, and the heat exchanger network (the third layer) can be designed. The remaining heating and cooling duties are handled by the utility system (the fourth layer). The process utility system may be a part of a centralized side wide utility system.

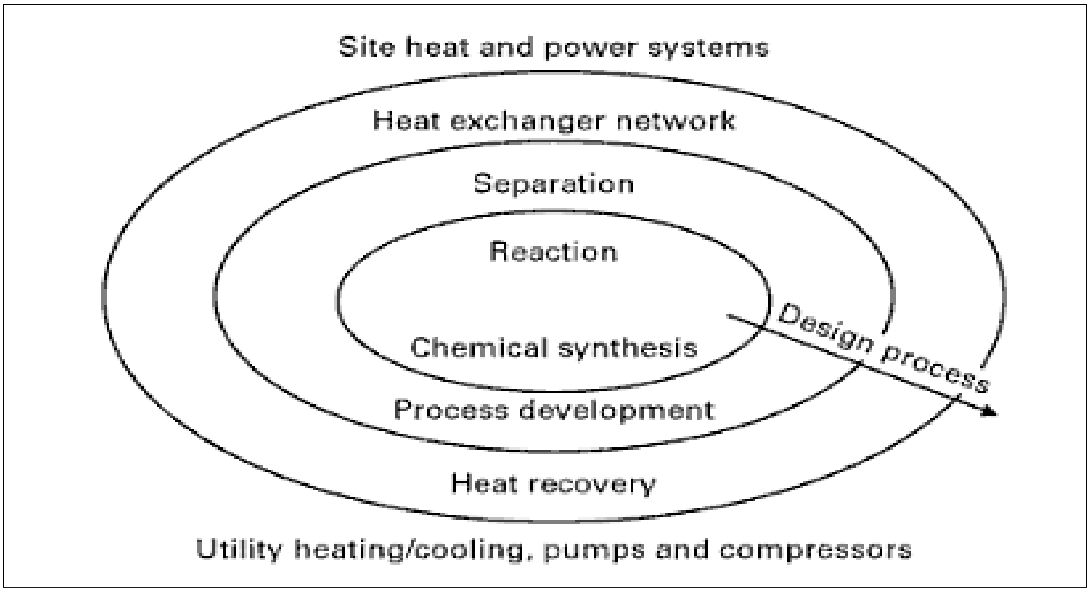

Figure 2.8: "Onion diagram" of process hierarchy in a process design (C.Kemp, 2007)

Using Pinch Technology, it is possible to identify appropriate changes in the core process conditions that can have an impact on energy savings (onion layers one and two). After the heat and material balance is established, targets for energy saving can be set prior to the design of the heat exchanger network. The pinch design method ensures that these targets are achieved during the network design. Targets can also be set for the utility loads at various levels such as steam and refrigeration levels. The utility levels supplied to the process may be a part of a centralized site-wide utility system. Pinch technology extends to the site level, where in appropriate loads on the various steam mains can be identified in order to minimize the site wide energy consumption. Pinch technology therefore provides a consistent methodology for energy saving, from the basic heat and material balance to the total site utility system.

2.3.1 Composite curve

The most fundamental concept in Pinch analysis is composite curves and grand composite curves. A composite curve visualizes the flow of heat between the hot and cold process streams selected for heat integration. A composite curve is